MRI estimation of dynamic regional lung ventilation, derived from pulmonary density changes during respiration

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INTRODUCTION

The observed MRI signal intensity (SI) from lung tissue varies with the respiratory phase due to changes in regional air content (Bankier et al., JMRI 20:961-6, 2004), possibly providing an estimator of regional lung ventilation. The underlying hypothesis is that lung SI changes are only due to regional lung extension, which implies that the integral of SI over the entire lung is constant during respiration. We test this hypothesis in a sagittal and a coronal 2D plane.

METHODS

Eight patients (pulmonary arterial hypertension(n=4), pulmonary emboli (n=4)) were referred to MRI on a 1.5 T Siemens 'Sonata' system. Magnevist[R] contrast agent was given at a dose of 0.2 ml per kg body weight for a lung perfusion study. Afterwards, the lungs were imaged during normal breathing with real-time cine SSFP imaging. TR/TE/flipangle were 2 ms, 1 ms and 50 deg. Voxel size was 4.2 x 3.1 x 15 mm, and temporal resolution 119 ms. Imaging planes were mid-sagittal through the right lung, and coronal behind the heart. The contour around the right lung was manually drawn, and the mean SI [a.u.] and the lung cross-sectional area [cm^2] were calculated. The integral of SI over the entire lung was calculated by the product of the mean SI and the lung cross-sectional area ('Area'). The hypothesis is then formulated by:

$$SI \times Area = constant, \text{ or: } \mathbf{\ln(SI) = -\ln(Area) + constant}$$

Thus the hypothesized relation of ln(SI) versus ln(Area) is linear with a slope of -1. This is tested by calculating SI and Area from expiration to inspiration, and then performing a linear regression of ln(SI) over ln(Area). The right lung was analyzed in coronal and sagittal planes (fig 1).

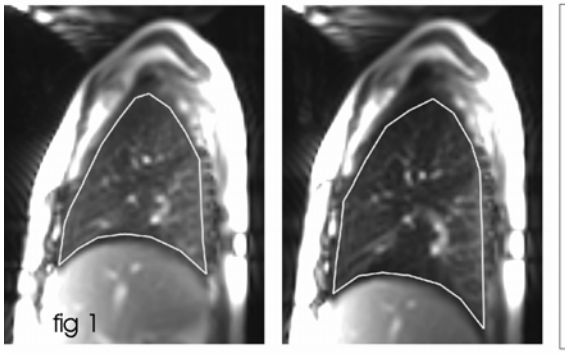

fig 1

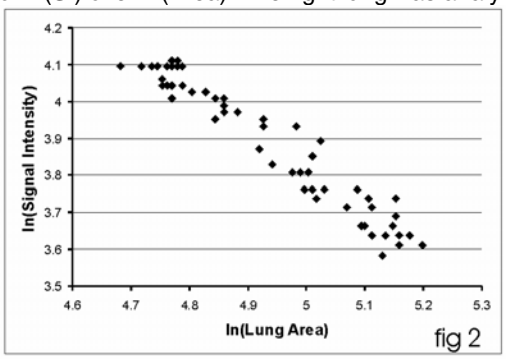

fig 2

RESULTS

The relative change in cross-sectional area from expiration to inspiration was 32 ± 15 % in the coronal plane and 37 ± 12 % in the sagittal plane, which was not significantly different between both planes. Fig. 2 shows the diagram of ln(SI) versus ln(Area) in the sagittal plane for 1 patient. The table summarizes the linear regression results of ln(SI) versus ln(Area) for the 8 patients.

	r^2	slope	p-value
Coronal plane	0.90 ± 0.09	-1.38 ± 0.51	<0.05
Sagittal plane	0.95 ± 0.02	-1.05 ± 0.17	<0.0001

For one pulmonary hypertension patient, the SI during respiration was plotted for 4 different lung regions in a sagittal plane (fig 3). The real-time SI changes during respiration are manifest, with SI decrease during inspiration, and SI increase during expiration (fig 4).

fig 3

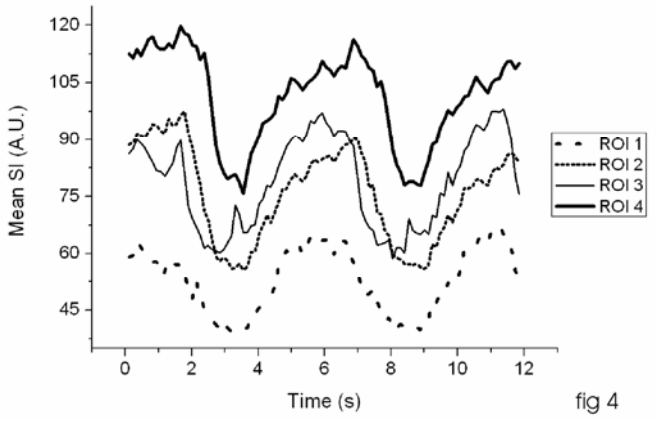

fig 4

DISCUSSION

In the coronal plane, the slope of the regression ln(SI) versus ln(Area) is on average -1.38, and thus more negative than the hypothesized value of -1. Thus during inspiration, the lung SI drops faster than expected from the hypothesized conservation of integrated SI. Also the standard deviation between patients is large. Presumably, through-plane motion of blood vessels and lung tissue occurs during inspiration in the posterior-anterior direction. Thus, the SI from the lung in the coronal plane is not only influenced by lung extension, but also by through-plane motion. However, in the sagittal plane this slope is on average -1.05 which is close to the hypothesized value of -1, and also the standard deviation between patients is smaller than in the coronal plane. The better conservation of integrated SI in the sagittal view is probably explained by less through-plane motion of lung tissue in the left-right direction. Thus in the sagittal view the change in lung SI is a better estimation of regional lung extension by ventilation, than in the coronal view.

CONCLUSION With real-time MRI, the pulmonary signal intensity change during respiration can be used as an estimator of dynamic regional lung ventilation. This estimation is more accurate in a sagittal imaging plane than in a coronal plane.